# Age and growth of megrim *Lepidorhombus whiffiagonis* (Scophthalamidae) from eastern central Adriatic Sea

by

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**Abstract**. – The age and growth parameters were analysed for *Lepidorhombus whiffiagonis* (Walbaum, 1792) collected in the eastern central Adriatic. Samples were collected monthly from January to December 2006 on the random basis, with a total of 1118 specimens analysed (538 males and 580 females). The values of b for males (3.166), females (3.212) and total (3.187) indicated positive allometric growth. Growth zones on otoliths revealed seven age classes, ranging from 1 to 7 years, including a high proportion of 2 years old individuals. The von Bertalanffy growth parameters were for males: $TL_\infty = 41.2$, $K = 0.152$, $t_o = -1.39$ years; for females $TL_\infty = 44.8$, $K = 0.166$, $t_o = -1.07$ years; and total: $TL_\infty = 55.0$, $K = 0.104$, $t_o = -1.61$ years. Growth parameters for males and females were not significantly different. This study revealed that megrim is a relatively slow growing fish with intensive growth during first two and three years of its life.


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**Résumé**. – Âge et croissance de la cardine *Lepidorhombus whiffiagonis* (Scophthalamidae) en mer Adriatique centre-est.

Les paramètres d'âge et de croissance de la cardine, *Lepidorhombus whiffiagonis* (Walbaum, 1792), ont été étudiés en mer Adriatique centre-est. Un total de 1118 échantillons (538 mâles et 580 femelles) collectés mensuellement (entre janvier et décembre 2006) a été analysé. Les valeurs de b pour les mâles (3,166), les femelles (3,212) et totales (3,187) ont indiqué une croissance allométrique positive. Les anneaux de croissance sur les otolithes ont révélé sept classes d'âge, allant de 1 à 7 ans, comprenant une très forte proportion d'individus de 2 ans. Les paramètres de croissance de von Bertalanffy ont été estimés pour les mâles : $L_\infty = 41,12$, $K = 0,152$, $t_o = -1,39$ ans ; pour les femelles $L_\infty = 44,8$, $K = 0,166$, $t_o = -1,07$ ans, et au total : $L_\infty = 55,0$, $K = 0,104$, $t_o = -1,61$ ans. Cette étude montre que la cardine est une espèce à croissance relativement lente, mais toutefois intense durant les deux ou trois premières années de vie.

The megrim, *Lepidorhombus whiffiagonis* (Walbaum, 1792) is a benthic scophthalmid fish, which inhabits the Mediterranean and eastern Atlantic (Nielsen, 1986). It is common in the central and south Adriatic on the muddy and sandy bottoms at depths of 20-260 m (Jardas, 1996). In the eastern Adriatic Sea, megrim is one of the main target species of the commercial trawl fisheries with an annual catch of about 5 tonnes (Jardas, 1996). Despite its abundance, little is known about the biology of this species in the Adriatic Sea. Some information about the distribution and spawning period are reported by Karlovac (1975) and Jardas (1996), while Šantić *et al*. (2009) noted feeding habits of megrim. Moreover, age and growth have not been analyzed for this species in the Adriatic Sea.

In the north-eastern Atlantic, growth of *L. whiffiagonis* has been studied by several authors (Rodriguez and Iglesias, 1985; Aubin-Ottenheimer, 1986; Peronnet and Rivoalen 1989; Landa *et al*., 1996; Landa and Piñeiro, 2000). Most authors determined the age-length relationship directly, using length at captures. Age from otoliths was studied only by Rodriguez and Iglesias (1985), and Landa and Piñeiro (2000) used back-calculation to study growth. Parameters of the Length/Weight Relationships (LWRs) were estimated by Merella *et al*. (1997), Özekinci *et al*. (2009) from the Mediterranean Sea and by Dorel (1986) in the eastern Atlantic.

Determination of age and growth rate is important in ichthyologic investigations, as fish growth is one of the main factors that determinate stock conditions (Pallaoro *et al*., 2008). Parameters of length-weight relationships have several applications, in the field of fish biology, physiology, ecology, and fisheries assessment. Furthermore, LWRs are fundamental for the estimation of weight-at-age (Petrarkis and Stergiou, 1995), production and biomass of fish population (Anderson and Gutreuter, 1983) as well as for comparisons of fish population from different regions (Gonçalves *et al*., 1997).

The aim of the present work is to determine age, growth and length-weight relationships of the megrim from the

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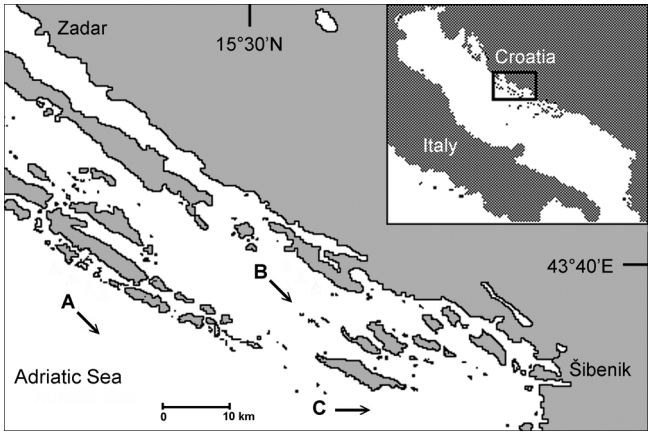


Figure 1. - Study area and sampling localities for *Lepidorhombus whiffiagonis* in the eastern central Adriatic. **A**: Kornati Archipelago. **B**: Murter Channel. **C**: South off Žirje. Arrows represent fishing directions.

eastern central Adriatic Sea. The findings of this study are important as they can be used to develop a management and protection strategy for this species in the Adriatic Sea.

## MATERIAL AND METHODS

Samplings of megrim were collected from three localities in the eastern Adriatic Sea on the continental shelf, mostly at depths of 90 to 120 m (Fig. 1). Fish were sampled with commercial bottom-trawls using a 22 mm stretched mesh size cod-end. Duration of each haul was 2-3 h and the trawling speed fluctuated from 5 to 7 km/h. Monthly random samples were collected from January to December 2006, with a total of 1118 specimens measured (538 males and 580 females). Total length (TL) of all specimens was measured to the nearest 0.1 cm, and body weight (W) to the nearest 0.1 g of fish after length. Sex was assigned macroscopically. Sagittal otoliths were removed, placed in water to remove surrounding membranes, cleaned and stored dry for age determination.

The relationship between weight and total length of fish, $W = aTL^b$, was converted into its logarithmic expression: $\log W = \log a + b \log TL$. Parameter $b$ is the exponent of the arithmetic form of LWRs and the slope of regression line in the logarithmic form (Froese, 2006). The value of $b$ exponent indicates isometric and allometric growth. The parameters $a$ and $b$ were calculated by least-squares regression, as was the coefficient of determination ($r^2$). Significant difference of $b$ values from 3, which represent isometric growth, was tested with the t-test (Pauly, 1983). Differences of b values between sexes were calculated by analysis of covariance (ANCOVA, $p > 0.01$; Zar, 1999). Sex ratio (males:females) for entire sample was estimated. A chi-square test was used to detect differences in the sex ratio of sampled fish.

Age readings were taken by examining the otoliths under a stereoscopic microscope, using reflected light against black background with the whole otoliths placed in water. Under low magnification, a series of successive concentric opaque and hyaline rings was noted radiating out to the otolith edge. Therefore an opaque ring and hyaline ring together represent one year's growth (Caillet *et al*., 1986). The hyaline rings were treated as annuli and were counted. Each otolith was read three times by three different readers. Only coincident readings of 1030 individuals (504 males and 526 females) were used. For validating the periodicity of annuli formation, the marginal increment ratio (MIR) on each otolith was computed according the formula (Jearld, 1983):

$$MIR = (O - r_n) / O$$

where $O$ = otolith radius and $r_n$ = radius of the most recent annulus. Mean of MIR was measured each month during the 2006 year. Mean length at age data, as derived from length frequency analysis, was used to estimate the growth parameters of the von Bertalanffy growth equation (von Bertalanffy, 1938):

$$TL = TL_\infty(1 - e^{-k(t - t_o)})$$

where $TL_\infty$ is the ultimate length that an average fish could achieve, K is the growth coefficient which determines how fast the fish approaches $TL_\infty$, and $t_o$ is the hypothetical age for TL = 0 cm. Maximum likelihood test (Kimura, 1980) was used for comparison of growth parameters for males and females.

The growth performance index ($\Phi$') was estimated to compare values of the growth parameters obtained in this study with those reported from the northeastern Atlantic. This index was calculated as follows (Munro and Pauly, 1983):

$$\Phi' = 2 \ln TL_\infty + \ln K$$

where $TL_\infty$ and K are parameters of the von Bertalanffy growth equation.

## RESULTS

Of the total fish examined (N = 1118), 538 were males and 580 females. All specimens were mature. The overall sex ratio was 1:1.07 in favour of females, and was close to the expected 1:1 sex ratio ($\chi^2 = 0.8$, $p > 0.05$).

The length frequency distribution of total samples (males and females) is shown in figure 2. The length frequency distribution exhibited a mode at 17 cm. Total lengths of males ranged from 9.0 to 29.5 cm (mean 17.9 ± 3.32 cm), and weight from 8.1 to 168.9 g (mean 66.2 ± 8.14 g) (Fig. 3A). Total lengths of females ranged from 10.9 to 35.9 cm (mean 19.5 ± 3.63 cm), and weight from 8.0 to 313.0 g (mean 114.3 ± 11.23 g) (Fig. 3B).

Length-weight relationships were calculated separately for males, females and for sexes combined. The values of $b$ for males ($b = 3.166$; $t = 3.84$; $t_{0.01}$; $t_{crit} = 2.58$), females

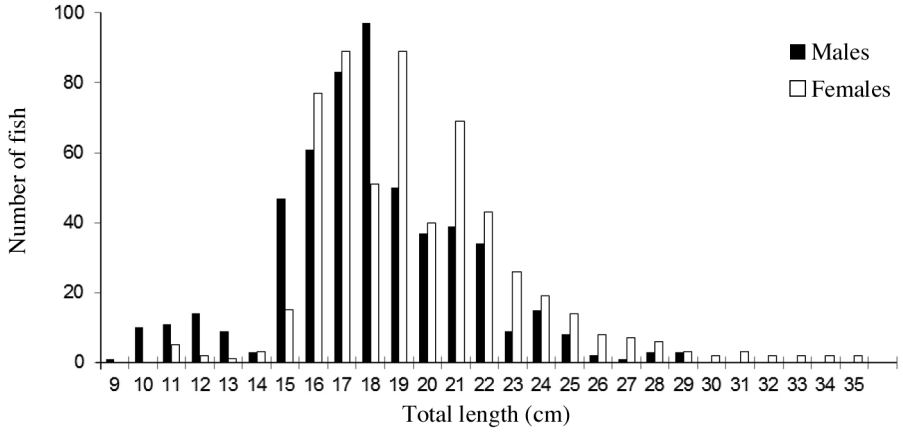


Figure 2. - Length-frequency distribution of *Lepidorhombus whiffiagonis* for males and females in the eastern central Adriatic Sea (n = 1 030).

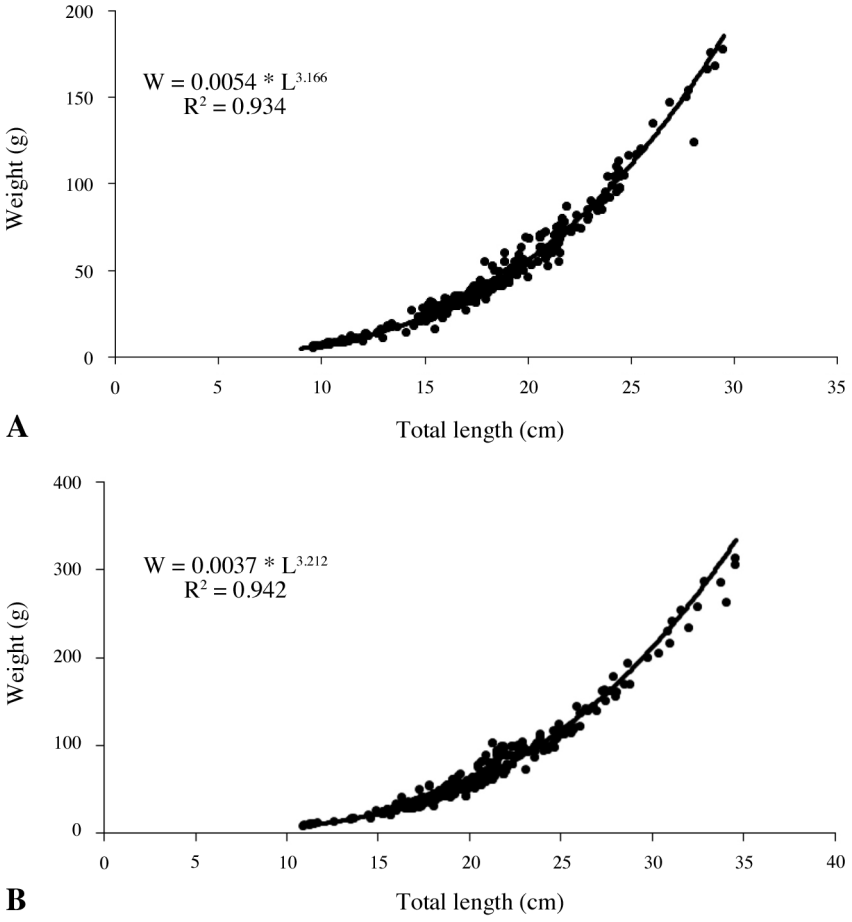


Figure 3. - Total length and weight range of *Lepidorhombus whiffiagonis* in the eastern central Adriatic Sea from January to December 2006. **A**: For 538 males. **B**: For 580 females.

($b$ = 3.212; $t$ = 5.74; $t_{0.01}$; $t_{crit}$ = 2.58) and sexes combined ($b$ = 3.187; $t$ = 5.11; $t_{0.01}$; $t_{crit}$ = 2.58) indicated positive allometry growth. No significant difference of $b$ among sexes was observed (ANCOVA, $p > 0.01$).

1030 otoliths of megrim were used for age study (504 males and 526 females). Otoliths showed clearly the ring patterns common to teleost fishes. The opaque zone was deposited during summer months (from May to August), while hyaline rings were formed throughout winter. The monthly variation of the marginal increment ratio confirmed the annual periodicity of the annulus formation, suggesting that the single annulus is formed each year during autumn-winter. The minimal mean of marginal increment ratio (MIR) was noted in July. Seven age classes, ranging from 1 to 7

Table I. - Age length key for sexes combined of *Lepidorhombus whiffiagonis* (N = 1030) based on otolith readings.

| Length range (cm) | Age (years) | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 9.5-10.4 | 1 | | | | | | | 1 |
| 10.5-11.4 | – | | | | | | | – |
| 11.5-12.4 | 1 | | | | | | | 1 |
| 12.5-13.4 | | | | | | | | – |
| 13.5-14.4 | | 4 | | | | | | 4 |
| 14,5-15.4 | | 52 | | | | | | 52 |
| 15.5-16.4 | | 80 | | | | | | 80 |
| 16.5-17.4 | | 163 | | | | | | 163 |
| 17.5-18.4 | | 156 | 44 | | | | | 200 |
| 18.5-19.4 | | 108 | 28 | | | | | 136 |
| 19.5-20.4 | | 32 | 40 | 8 | | | | 80 |
| 20.5-21.4 | | 4 | 71 | 24 | | | | 99 |
| 21.5-22.4 | | | 47 | 4 | | | | 51 |
| 22.5-23.4 | | | 16 | 8 | | | | 24 |
| 23.5-24.4 | | | 12 | 14 | 9 | | | 35 |
| 24.5-25.4 | | | 12 | 22 | 5 | | | 39 |
| 25.5-26.4 | | | 4 | – | 5 | | | 9 |
| 26.5-27.4 | | | | 6 | 9 | | | 15 |
| 27.5-28.4 | | | | 4 | 8 | 1 | | 13 |
| 28.5-29.4 | | | | 4 | 4 | – | | 8 |
| 29.5-30.4 | | | | 8 | 4 | – | 1 | 13 |
| 30.5-31.4 | | | | | 4 | 2 | | 6 |
| 31.5-32.4 | | | | | | – | | – |
| 32.5-33.4 | | | | | | – | | – |
| 33.5-34.4 | | | | | | – | | – |
| 34.5-35.4 | | | | | | 1 | | 1 |
| N | 2 | 599 | 274 | 102 | 48 | 4 | 1 | 1 030 |
| % | 0.2 | 58.1 | 26.6 | 9.9 | 4.6 | 0.4 | 0.1 | |
| Mean | 10.8 | 17.4 | 20.8 | 24.4 | 27.7 | 31.2 | 29.9 | |
| SD | 1.62 | 1.29 | 2.00 | 3.01 | 3.06 | 2.66 | 0 | |

years, were defined by otolith readings (Tab. I). As shown in table II, age composition varied from 1 to 7 for males and 1 to 6 for females. According to the frequency of occurrence, age class 2 was dominant for both sexes (Tab. II). In the age classes from 1 to 5 years, observed mean TL of females were greater than those of males. The mean lengths of individuals assigned to each age class were used to fit the von Bertalanffy growth parameters for each sex and their data combined (Tab. III). The estimated K in the growth equation for females (K = 0.166), males (K = 0.152) and sex combined (K = 0.104) indicated slow growth of megrim. Growth parameters for males and females are not significantly different (Max. likelihood test: L = 2.89, $C^2_{005,3} = 7.98$, $p > 0.05$). According to the obtained von Bertalanffy growth equation, megrim shows intensive growth during the first two and three years of its life (Fig. 4). Values of growth performance

Table II. - Number (n), mean ± standard deviation (SD) values of total length (cm) for *Lepidorhombus whiffiagonis* males and females within each age class.

| | Males | | Females | | Total (n) |
|---|---|---|---|---|---|
| Age (years) | n | Mean ± SD | n | Mean ± SD | |
| 1 | 1 | 9.6 ± 0.00 | 1 | 11.9 ± 00.0 | 2 |
| 2 | 272 | 16.7 ± 0.98 | 327 | 17.9 ± 1.27 | 599 |
| 3 | 161 | 19.9 ± 1.76 | 113 | 22.0 ± 1.66 | 274 |
| 4 | 49 | 22.9 ± 1.84 | 53 | 25.4 ± 3.27 | 102 |
| 5 | 20 | 26.2 ± 2.29 | 28 | 28.4 ± 3.26 | 48 |
| 6 | – | – | 4 | 31.2 ± 2.66 | 4 |
| 7 | 1 | 29.5 ± 0.00 | – | – | 1 |

Table III. - The Von Bertalanffy growth parameters for *Lepidorhombuswhiffiagonis* from the eastern central Adriatic Sea.

| Sex | $L_\infty$ | ± SE | K | ±SE | $t_o$ | ± SE | $r^2$ | n |
|---|---|---|---|---|---|---|---|---|
| Males | 41.2 | 3.23 | 0.152 | 0.043 | -1.39 | 1.10 | 0.979 | 504 |
| Females | 44.8 | 4.11 | 0.166 | 0.030 | -1.07 | 0.90 | 0.985 | 526 |
| Both sexes | 55.0 | 3.98 | 0.104 | 0.033 | -1.62 | 0.78 | 0.973 | 1030 |

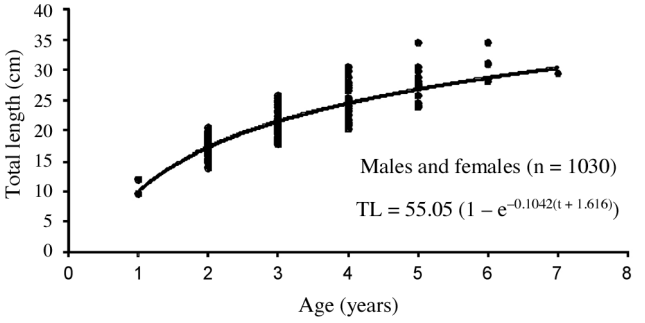


Figure 4. - Von Bertalanffy growth curve for combined sexes (n = 1030) of *Lepidorhombus whiffiagonis* in the eastern central Adriatic Sea.

index (Φ') for males were 5.60, for females 5.70, and 5.75 for sex combined.

## DISCUSSION

The exponents of the length-weight relationships for males ($b = 3.166$), females ($b = 3.212$) and sexes combined ($b = 3.187$) estimated in the eastern central Adriatic, showed that growth of megrim was positively allometric, meaning it is slightly faster in weight than in length. Similarly, positive allometric growth is noted by Merella *et al*. (1997) for the western Mediterranean ($b = 3.26$) and by Dorel (1986) for the eastern Atlantic ($b = 3.24$). Closely related species regarding morphology and size, *Lepidorhombus boscii* (Risso, 1810) also showed positively allometric growth in the southern Adriatic Sea ($b = 3.26$) (Bello and Rizzi, 1987). On the other hand, negative allometric growth of megrim ($b = 2.32$) was recorded in the north Aegean Sea (Özekinci *et al*., 2009).

Table IV. - The Von Bertalanffy growth parameters and growth performance index (Φ') for males and females *Lepidorhombus whiffiagonis* in the northeastern Atlantic (ICES division VII) and this study (eastern central Adriatic)

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| Authors | $TL_\infty$ | K | $t_o$ | Φ' | $TL_\infty$ | K | $t_o$ | Φ' |
| Rodriguez and Iglesias (1985) | 39.36 | 0.29 | 0.14 | 6.10 | 63.13 | 0.11 | -0.07 | 6.08 |
| Aubin-Ottenheimer (1986) | 38.40 | 0.34 | -0.06 | 6.21 | 60.20 | 0.14 | -0.05 | 6.22 |
| Moguedet and Pérez (1988) | 43.67 | 0.14 | -1.76 | 5.58 | 65.20 | 0.09 | -1.87 | 5.94 |
| Peronnet and Rivoalen (1989) | 44.80 | 0.14 | -1.76 | 5.63 | 66.80 | 0.11 | -0.33 | 6.19 |
| Landa *et al*. (1996) | 46.00 | 0.14 | -1.25 | 5.69 | 66.00 | 0.13 | 0.38 | 6.33 |
| Landa and Piñeiro (2000) | 43.70 | 0.16 | -0.15 | 5.72 | 62.70 | 0.14 | 0.40 | 6.31 |
| This study | 41.20 | 0.16 | -1.39 | 5.60 | 44.80 | 0.15 | -1.07 | 5.70 |

These differences probably reflect the growth variations due to environmental factors such as temperature and salinity in the different areas of investigation. For instance, the average annual surface sea temperature of the northern Aegean Sea is 15-17°C with an average salinity of 33 (Poulos *et al*., 1997), whereas the average annual surface temperature in the central Adriatic ranges between 14 and 25°C with salinity of 38.3 (Zore-Armanda *et al*., 1991). In addition, possible genetic differences between populations from different areas, as well as gear selectivity, level of exploitation, variations in fish shape and stomach fullness, can also affect the value of *b* (Shepherd and Grimes, 1983; Mommsen, 1998).

Previous research has shown that fish species in temperate waters form annuli surface rings as a result of reduced growth in winter, caused by declining seawater temperature and decreased of food availability (Morales-Nin, 1989). Otoliths of megrim showed clearly the ring pattern confirming such theory common to teleost fish with annuli ring formation during the summer month. In the present study, estimates of K indicated that Adriatic megrim is a relatively slow growing fish. Namely, the area of the eastern-central Adriatic is one of the most oligotrophic areas of the Adriatic Sea, which could possibly explain the slower growth of megrim. Both males and females exhibit the fastest growth during the first two years of life, while afterwards their growth slows down. Slower growth is due in part to higher energy expenditure on increased reproductive processes, whereas faster growth in early years of life is a general characteristic of flatfish (Florin, 2005).

The lack of age and growth data for Adriatic and Mediterranean megrim does not allow comparisons of grow parameters, but there are more studies related to the estimation of von Bertalanffy growth only in the north eastern Atlantic (ICES Division VII) (Tab. IV). In the present study, otolith analyses showed that the oldest male was 7 years old and the female 6. The maximum age obtained in the present study is lower than that observed by Landa and Piñeiro (2000), who found the oldest specimens from the north eastern Atlantic to be 13 years old. However, mean length at age of males and females estimated in eastern Atlantic (Landa *et al*., 1996) were higher than our results. In the eastern Atlantic, Landa and Piñeiro (2000) noted north-south gradient growth, with greater age range and maximum lengths in the northern areas. Furthermore, cool waters produce larger, older, later-maturing individuals of species than warm waters do (Ross, 1988). Similar results are reported by Pallaoro (1996) and Zorica (2003), comparing Adriatic saddlead bream [*Oblada melanura* (Linnaeus, 1758)] and lettered perch [*Serranus scriba* (Linnaeus, 1758)] with populations of these species in colder seawaters.

Calculating a growth performance index, our result showed relatively small differences from those reported in the northeastern Atlantic. Some differences in growth rates could be explained by the conditions of the Adriatic Sea, as the northernmost part of Mediterranean, which is a specific oceanographic area where influence of geographical, geomorphological, climatic and other different environmental factors, mostly of hydrographic nature, is crucial for its characteristics (Jardas, 1996). Moreover, the peculiarities of the Adriatic ichthyofauna depend on these factors, which possibly affect growth characteristics of marine organisms. In addition to aforementioned, it is necessary to add variations in the diet and availability of prey between areas, which also influence growth (Landa *et al*., 1996). In the eastern Adriatic Sea, megrim is the object of intensive commercial fishing, especially by bottom-trawls. Possibly, intensive fishing of these species is the cause of low proportion of specimens older than 5 years in the catches. Namely, high fishing pressure leads to a decrease in maximum length of fish (Rice, 2005). For instance, maximum length for this species recorded in the Adriatic Sea is 50 cm (Karlovac, 1975), which is significantly larger than maximum length obtained in this study (TL = 35.9 cm).

In present study, despite that growth parameters of males and females were not significantly different, the length frequency distribution showed that females are slightly longer than males. These results coincide with those of other authors from the eastern Atlantic (Tab. IV). The differential length between sexes may be related to differences in metabolic activity, this being more marked in males, with higher oxygen consumption (Pauly, 1994a, 1994b, 2010). Furthermore, this difference possibly caused various levels of surplus energy between reproduction and somatic growth (Rijnsdorp and Ibelings 1989; Pauly, 2010).

In conclusion, growth of megrim in the eastern central Adriatic was slightly faster in weight than in length. The age composition varied from 1 to 7 for males and 1 to 6 for females. This study revealed that megrim is a relatively slow

growing fish with intensive growth during first two and three years of its life.

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